Social Networks and Optimal Marketing Strategies for Diffusion: Does ABM Tell Us More?

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Section 1: Rationale for the study

In this paper my broad research objective is to evaluate the impact of two competing change agents on adoption decisions of a group of clients who are connected to each other by social or professional ties. A change agent is termed as an individual or organization attempting to influence clients' adoption decisions in a direction deemed desirable by a change agency (Rogers 1995). The roles of a change agent have been discussed thoroughly in diffusion literature for a broad range of cases. By adopting an ABM framework, the novelty of my exploration originates from evaluation of the incentive mechanism for change agents like pharmaceutical companies involved in strategic interactions. Based on an earlier work in *Gammanym* model (http://cormas.cirad.fr/en/applica/gammanym.htm), this model, *Gammanym2*, depicts how the competing prescription drugs diffuse through a medical community. *Gammanym2*, thereby, attempts to provide the rationale for optimal marketing strategies in case of repeated games.

I describe the modelling framework in the following section. The rationale for marketing strategies, using the central idea of *Prisoners' Dilemma* has been discussed in Section 3. Simulation results under different scenarios are analysed under Section 4. The Paper concludes with a brief description of work in progress.

Section 2: Modelling Framework

Using SMALLTALK programming language, *Gammanym2* has been developed with the CORMAS platform under *Visual Works* environment. First, the attributes and methods of three principal agents are discussed in Section 2.1. Decision-making processes by the social agents are then discussed. This section concludes with discussion on rationale for strategic interventions by the pharmaceutical companies.

2.1 Spatial Representation and Passive Objects

A medical community of 990 doctors is represented in a 27 X 19 spatial grid. The unit cell captures three different locations for professional interactions: Hospitals, Practices and a Conference Centre, which are created as passive objects. To capture the impact of different degrees of professional integration, I specify three kinds of practices: *Private* (alone in office), *Centre* (shared office with two partners) and *Clinic* (working with four colleagues). Uniform distribution of doctors in terms of their professional integration has been modelled with 330 doctors in 330 private practices, 330 in 110 centres and 330 in 66 clinics.

Primarily, the doctors interact with the office colleagues at their practices. Two hospitals and one conference centre provide the context in which an agent gets the chance to interact with much larger group. The doctors have their monthly visits to two hospitals. The doctors are initiated with an attribute, *counter for hospital*, ranging from 0 to 3. *Counter for hospital* is an attribute that specifies the frequency of hospital visit i.e. the doctors randomly choose one of the hospitals when the counter for hospital is 4. Conference centres is the third entity for professional interaction. The invitations to conferences are sent randomly to 300 doctors. Doctors receive the invitation and move to the conference centre if they are available at their practices at the time step when the invitations are sent.

2.2 Social agents

Gammanym2 depicts two kinds of social agents - *Doctor* and *Laboratory*. Initially located in their respective practices, *Gammanym2* considers doctors as the principal agent in the diffusion process. The main objective of

the two pharmaceutical laboratories are to influence doctors' adoption decisions by sending information through multiple channels (Schweitzer 1997) like medical representatives, journal advertisement, direct mail etc (labs and pharmaceutical companies are interchangeably used in this text).

2.2.1 Located and Communicating Agents: Doctors

The diffusion processes of two competing drugs are investigated for two sets of doctors: *homogenous* doctors with only network variables; and *heterogenous* agents with individual as well as network variables.

All doctors are initiated with varied degrees of professional and social integration. Professional interactions are spatially defined and are created through discussions with office colleagues at their respective practices, or through hospital visits or conference attendance, or all of the above. This specification signifies the importance of tacit knowledge or non-codified knowledge, which requires face-to-face contacts for its transmission. The doctors, therefore, consider the colleagues as discussion partners if they are situated in the same cell. Office partnership is central to professional networks as the doctors return to their practices after each visit to hospitals or conference centres. In case of hospital visits or conference attendance the doctors randomly selects 5 acquaintances to asses their evaluation of the new drug and decides based on the mean adoption rate of his acquaintances. The friendship network is random in nature as the doctors are initialised with random number of friends and *counter for friends*; both ranging from 0-3. *Counter for friends* is an attribute that specifies the frequency of communication i.e. doctors communicate with their friends when the counter for friends is 4.

For heterogenous agents, decision-making processes by the doctors depend on two individual/personal attributes: *uncertainty* and *preference*. Each doctor is initiated with a real number, between 0 and 2, which refers the *uncertainty,* which represents their attitude towards newness/unknown. Preference, β, on the other hand, signifies the general notion of differences in perceptions towards different sources of information-acquaintances and labs. In other words, doctors have different perceptions towards evaluating the information from the change agency and their peers (friends/colleagues). Granovetter (1978) initiated the research on thresholds in the diffusion of innovations by postulating that individuals are not homogenous in the degree they are influenced by the social system. Thresholds, therefore, are normally distributed inn *Gammanym2*. Hence, β is initiated as a normally distributed real number valued between 0 and 1.

2.2.1.1 Adoption decisions

Diffusion scholars have long recognized that an individual's decision about adoption is a process that occurs over time, consisting of several stages (Coleman, Katz and Menzel 1966; Rogers 1995, Abrahamson and Rosenkopf 1997, Valente 1995). In *Gammanym2* readiness is specified as the attribute signifying five stages of adoption: i. Awareness or knowledge, ii. Interest, iii. Evaluation/mental trial, iv. Trial, and v. Adoption/acceptance. All doctors are initialised with readiness 4 for each of the drugs-drug 1 and drug 2; as attributes- '*readiness for Lab1'* and '*readiness for Lab2'* respectively.

The rationale for adoption decisions are drawn from the literature on diffusion of new product and ABM (Bass 1969, Edwards, Huet, Goreaud and Deffuant 2003, Granovetter and Soong 1986, Deffuant, Huet and Amblard 2005). In *Gammanym2*, doctors' adoption decisions crucially depend on alerts. Discussions with other doctors, either friends or colleagues at practices, conferences, or hospitals generate an alert when the mean adoption rate of the discussion partners is 0.50 or above. On the other hand, an alert is created each time a doctor receives information from the detailman or sales representative, flyers or journals. For homogenous doctors, reduction in readiness is proportional to number of alerts received irrespective of the sources. In other words, they move to the next stage of adoption when they receive a single alert (or more) from any of the aforementioned sources.

Heterogenous doctors, on the other hand, move to next stage of adoption according to a threshold function. At each time step, a temporary variable *opinion* is generated, based on a threshold function:

Opinion = $\beta(x) + (1-\beta).y$.

Here, x represents number of alerts received from pharmaceutical companies and y represents number of alerts generated from his social and professional acquaintances. At each time step, the doctors decrease their readiness for the respective drug or move to the next stage of adoption if the opinion variable is higher than their uncertainty. In case of agents with zero uncertainty, the risk lovers, I specify that this method of decrement of readiness is adopted only after they are aware of the drug i.e. when their readiness is 3 for the concerned drug[i].

When the readiness for a particular drug reaches zero i.e. doctors reach adoption or acceptance stage; the particular prescription drug is adopted. I opted for random switching between the two products. Random switching can be rationalized on the ground that product differentiation has not been incorporated in *Gammanym2*. When the doctors reach the adoption stage for both the drugs at the same time step, they choose randomly between the two drugs[ii]. However, as the doctors can switch between products, the readiness for both labs changes from zero as the doctors move back to trail stage (i.e. readiness is 1) for the adopted drug and to the interest stage (i.e. readiness is 3) for the other drug. The rationale for going back to interest stage, instead of awareness stage has been derived from the concept of interconnectivity between the two products (Redmond 2004). I assume, the two drugs have some degree of interconnectivity, as they are prescribed for the same illness. So when they are adopting one drug, they have some exposure about the information for the other drug and when they are reassessing their decision they would, not necessarily, go back to the awareness stage.

2.2.2. Located Communicating Agents: Laboratory

In this model two competing pharmaceutical labs, Lab 1 and Lab 2, are symmetrically located over the spatial grid. Among the six means of drug promotion (Schweitzer 1997), I consider three principal means for this study: detailman or sales representative, advertisement in medical journals and flyers sent at the conference centre.

The diffusion literature and policy debates surrounding pharmaceuticals' marketing strategies (Moynihan 2003, Blumenthal 2004, Andaleeb and Tallman 1996) identifies detailman as one of the most important, and quite often as the first sources of information. In *Gammanym2*, detailman visits all the doctors at their practices. At each time step each lab keeps records of the practices visited by the detailman and randomly choose one of the remaining practices or available practices, only if at least one of the doctors is present at the practice. As the time step refers to one week, so the detailman is able to contact all the doctors during his visit.

Advertisement in the medical journals is considered as another marketing tool. Journals, for each of the drugs are sent to all the practices and thereby ensure a blanket exposure to all doctors at the same time step. The model specifies issuance of quarterly journals[iii]. From the perspective of the pharmaceuticals, inclusion of flyers is crucial as it adds another dimension to the marketing mix by targeting a large group of doctors at the same time. To avoid the notion of blanket exposure to all doctors, we specify the criterion that the labs send flyers based on the number of previous conference participants. Receiving information from a flyer is therefore conditional upon number of available flyers and not all the doctors attending the conference receive the flyers. Given the focus of this study, to identify the optimal marketing strategy for the labs, the two relevant variables are: cost function and payoff function.

2.2.2.1 Cost function

The cost function is the summation of cost of sending the detailman, fixed costs for expenditure on research and development (R&D) and cost of advertising in the journal. As the cost of advertising in the journal and printing flyers is fixed[iv], total cost at each time step can be represented as: **Total Cost = FC + λ f(distance).** Distance in this case, is interpreted as the minimum distance travelled by the detailman from the regional centre for each lab, symmetrically placed over the spatial grid. For the sake of simplicity, I opt for a linear cost function. λ is the parameter representing marginal cost of travelling to practices.

2.2.2.2. Payoff function

The payoff function is defined as the ratio of number of adopted doctors and total cost. In other words, payoff measure is an output-input ratio or productivity measure. Thus, payoff is considered as an evaluation indicator, based on which the payoff matrix under different scenarios will be constructed in an attempt to determine the most effective marketing strategy.

Section 3: A Game Theoretic Exploration with Marketing Strategies

This model examines a simple game with a theoretical exposition originating form *Prisoner's Dilemma*. Core assumption is that the two competing pharmaceutical companies, despite the high cost of negotiation/transaction cost, have the incentive is to reduce their operation cost through regionalisation when each send their detailman to an allocated region. The firms, thereby, reduce the cost of traveling and hence increase the payoff.

3.1. Benchmark Scenario: Random Marketing

As the benchmark scenario, I consider the following scenarios for homogenous and heterogeneous doctors:

a. *Strategy I: Individual operation*; randomly targets doctors from the whole medical community. Though the companies vary in terms of their expenditure for R &D, for the sake of simplicity I assume the companies have the same fixed cost. No negotiation cost is involved in this case.

b. *Strategy II: Joint Operation*; the companies negotiate to conduct a joint operation and each covers a particular region.

c. *Strategy III: Defection;* the company initiating the negotiation bears the whole of negotiation cost and send detailman to the allocated region. The other company, despite signing agreement for joint operation continues with the individual operation and thus, covers the whole area.

All the scenarios have been run over 200 weeks to capture the dynamics of interaction better. As several random functions are included in the algorithm, each scenario is repeated 50 times in order to estimate the output's variability. For each of the cases, the seed or the innovator is chosen among the doctors who are practicing at centres, i.e., doctors who have two colleagues.

For the pharmaceutical companies, each are initiated with the same fixed cost of 2 million dollars. The unit cost of traveling or λ is specified as 1000 dollars. The negotiation cost is specified as 3 million dollars, so that in case of strategy 2 each lab is initiated with a fixed cost of 3.5 million dollars.

Given the focus of the paper, simulation results are represented in terms of payoffs only expressed in terms of number of adopted doctors per million dollar spent in launching the new product under different scenarios. The payoff matrix has been constructed with the highest payoffs for each of the labs:

Table 1: Payoff Matrix for Homogenous Social Agents

Lab 2

Lab1		Don't cooperate	Cooperate
	Don't cooperate	85, 101	124,38
	Cooperate	38, 131	69,76

Table 2: Payoff Matrix for Heterogeneous Social Agents

Lab2

Lab1		Don't cooperate	Cooperate
	Don't cooperate	46,46	48,23
	Cooperate	21,67	32,35

Both the matrices reveal a dominant strategy (do not cooperate) Nash Equilibrium outcome. This outcome implies, with a high negotiation cost and very small marginal cost of traveling, regionalisation is not optimal and the companies are better off to carry on individual operation for the whole medical community. Interesting to note that payoffs for heterogeneous agents are much smaller because of lower adoption rate[v].

3.2. Experimenting with Repeated Games Scenario

This section gives an overview of my work in progress regarding repeated games. The vast literature in game theory and innovative works combining game theory and ABM (Moss 2001, Axelrod 1997) needs to be read and incorporated to develop the theoretical rationale for experimentation with repeated games. But my exploration, at this point on time, is aimed at evaluating the implication of trade off between cost of marketing and coverage in terms of adoption. Assuming imperfect information exchange among the pharmaceuticals, I investigate with the following *Tit-for-Tat* strategies[vi]:

i. *Random marketing* with increased number of detailman targeting all doctors,
ii. *Segmented marketing* by prioritising the groups based on their professional integration with the same number of detailman.

Rationale for Segmented marketing evolves from the assumption that pharmaceutical companies are well aware of impacts of social networks on diffusion. As it will be easier for the pharmaceutical companies to gather information on doctors' professional integration (public information), they prioritise the most connected ones (who works in a practice with 4 colleagues i.e. in a clinic). So the company keeps on sending the detailman to the clinics until all of them are adopted and then target the doctors with second degree of professional integration, the doctors at the clinics and the private practices thereafter.

Important is to note that, I investigate with the core idea of *grim trigger strategy* only for the cheated company. A *grim trigger strategy* is one in which a player cooperates if the other player cooperates but if in any period the other player cheats, then choose Nash Equilibrium strategy in every subsequent period (Osborne 2004:420). In this section, my assumption is despite the retaliatory action by the other company the cheating company, lab 1, does not alter its strategy.

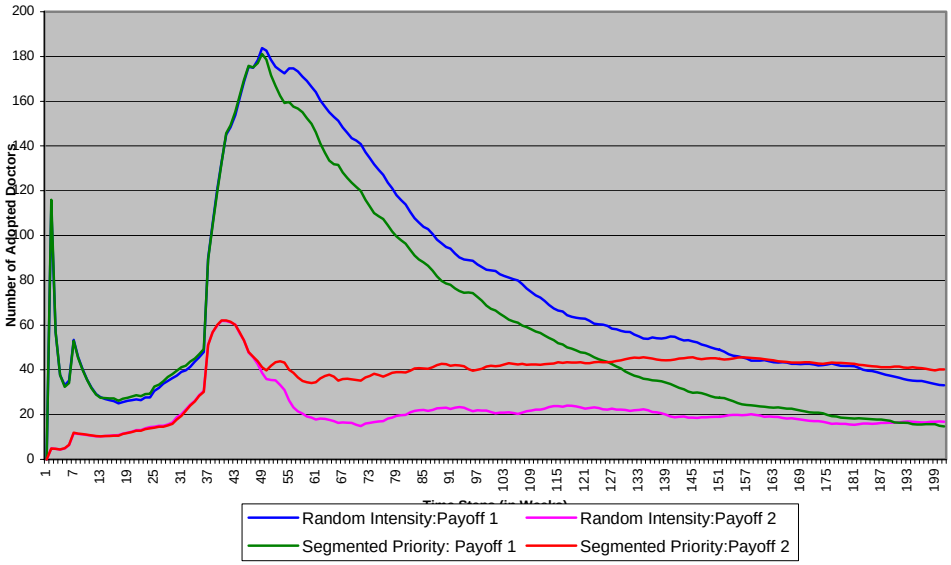

Fig 1: Optimal Tit-for-Tat Strategy: Comparison between Random and Segmented Marketing

Fig 1 represents payoff curves for lab 1 and lab2 when lab 2 retaliates to cheating by lab 1. In these scenarios, the initial adopters are located at their respective zones assigned to the particular pharmaceutical company. This implies all 10 initial adopters of drug 1 are located at zone 1, the operation zone for lab 1. Committing company bears the entire negotiation cost (Strategy III), the company has a system of quarterly evaluation. The evaluation criterion is based on the extent of influence by the other pharmaceutical labs on the doctors of the allocated operation zone. So, lab 2 will evaluate if the number of doctors adopting drug 1 is higher than one third of the total doctors in zone 2. If so, lab 2 will adopt one of above *Tit-for-Tat* strategies.

Is accessibility of the information on social networks of doctors helpful? This was my objective for investigation with the above-mentioned strategies. Fig 1 shows that segmented marketing ensures a better outcome in comparison with random intensity. In case of retaliation by segmented marketing gives a better outcome than the cheating company after 121 time steps. In case of random marketing, the retaliating company, Lab 2, fails to catch up even after doubling the number of detailman. Thus, optimal marketing strategy for the pharmaceutical companies needs to have access to information on doctors' social and professional integration.

Section 5: Work in Progress

In this section I will briefly discuss some preliminary results from my exploration with the concept of opportunity cost associated with trust, and complete regionalisation. The concept of opportunity cost of trust stems from the idea that the firms incur a cost when they commit to negotiate. In this study, opportunity cost of trust, hence, is the cost of monitoring the opponents' activities. Though set arbitrarily in this model, opportunity cost of trust captures the notion of cooperation in a better manner as it substitutes the idea of negotiation cost being borne entirely by the committing company (earlier specified as part of Strategy III). Now, each firm starts with two different values for trust cost. The committing company or the company initiating the negotiation has a higher opportunity cost of trust (*trust cost* from hereon). The cheating company, having different perceptions about negotiation i.e. not to cooperate, attaches lower value to the trust cost. Trust cost, unlike the fixed cost component may change at the time of (quarterly) evaluation based on the behaviour of the opponent. In this model, each firm changes their trust cost when their prior beliefs regarding the opponent changes. Our specification for evolving trust cost basically captures the notion of learning (Osborne 2004). As part of discussing the formation of players' beliefs, Osborne (2004)

describes learning as a scenario where the same set of participants repeatedly play a game, each participants changing her beliefs about the others' strategies in response to observations of their actions. In *Gammanym2* the value of trust cost decrease when the committing company becomes aware of the cheating by their opponent. I am currently reviewing the literature to develop the specification for evolution of trust cost further.

Figure 2 represents my exploration with evolving trust cost in case of complete regionalisation when both the firms adopt grim trigger strategy. Complete regionalisation[vii] is experimented as part of my attempt to evaluate the impact of visit by detailman on firms' payoff. Complete regionalisation implies that the only possibility for the committing pharmaceuticals to reach the doctors of the other region is through journal advertisements and flyers at the conference centres. The doctors are, therefore, specified to visit the regional hospital and the conference centre. It is important to note that in the previous section the cheating company does not alter its strategy despite retaliation by the committing company. For fig 2, both companies retaliate. The committing company assess the cheating and retaliates at the first quarterly evaluation. The cheating company becomes aware of the retaliation at the next quarterly evaluation (at 24 time steps) and retaliates in similar manner.

In comparison to Fig 1, the impact of segmented marketing is much higher in case of complete regionalisation. For the committing company, lab 2 in this case, retaliation by segmented marketing provides a higher payoff within 16 time steps. In case of random marketing, the result is similar to Fig 1 as the retaliating company fails to catch up with the payoff for cheating company i.e. lab 1. The differences between the payoffs of the two companies are, however, smaller due to complete regionalisation. The results, therefore, indicate that the information on social networks becomes more crucial if the diffusion is aimed for a secluded/isolated region.

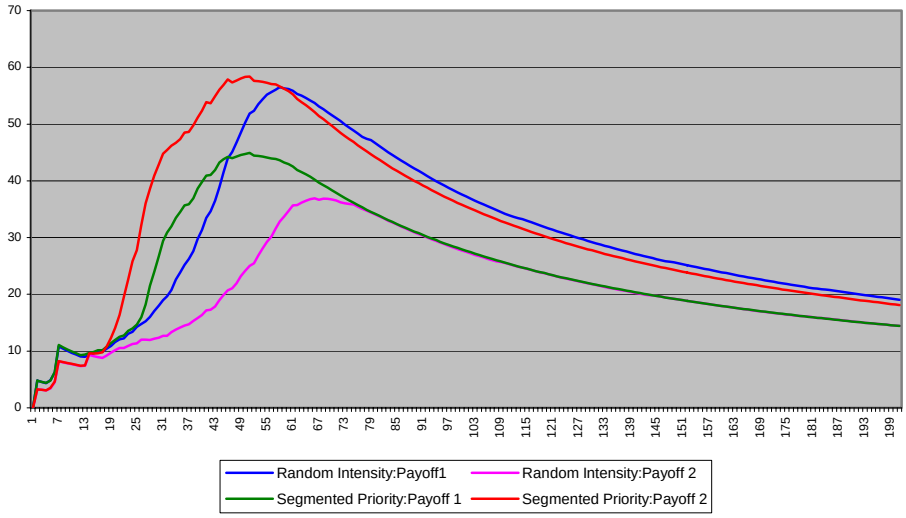

Fig 2: Optimal Tit-for-Tat Strategy under complete regionalisation: Comparison between Random and Segmented Marketing

My current work also involves identifying the optimal *Tit-for-Tat* strategy for heterogenous agents and evaluating the diffusion process involving three pharmaceutical companies. In case of heterogenous agents, it would be interesting to analyse if the information on social networks remain effective as a policy guideline for quicker diffusion. For three pharmaceutical companies, my principal research interest is to find if the concept of *economies of scale* holds true for cooperation. I plan to analyse if it is better to cooperate when the majority of players cooperate. Based on the results of the above, the next stage will be to investigate the payoff dynamics when the firms consider renegotiation after period(s) of retaliation.

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[i] These groups of agents were initiated to verify the importance of distribution of population and influence of extremists on diffusion process. Simulation results with different distribution of population shows that the number of extremists does not matter unless the average threshold of population varies.

[ii] I tested with uncertain adoption (assuming, the doctors remain uncertain if they reach readiness zero for both the drugs at the same time), which constitutes approximately 10% of population. When their reassessment capacity (the uncertain doctors reassess their decision after 4 weeks or so) was incorporated, I found the same result as Strategy 1.

[iii] The drug companies do not publish journals, but adding a publisher sending journal would not add much to the study, as it is hard to articulate other responsibilities for the publisher relevant to this model.

[iv] The payment for advertisement in a medical journal is fixed for all pharmaceutical companies, irrespective of their types. Given the competitive market structure, the cost of flyers are less likely to be very different.

[v] 21% of population has adopted each of the drugs in case of strategy I.

[vi] Prioritising the professionally integrated doctors has proved to be the most effective strategy in for a single lab, followed by random marketing with increased intensity of instrument.

[vii] The payoff matrix for benchmark scenario with random marketing under complete regionalisation reveals cooperation as the dominant strategy.